LONG-TERM ECOLOGICAL RESEARCH

A U.S. researcher works in a temporary laboratory set up in the McMurdo Dry Valleys for the McMurdo Long-Term Ecological Research project. *(NSF photo by Peter West)*

Ecology has taken its place among science's vital, strategic disciplines, thanks to an ever-greater awareness of how the web of life and the Earth's other dynamic processes constitute a closed and coherent system. As part of this evolution, the National Science Foundation's Long-Term Ecological Research (LTER) program, begun in 1980, has grown into a network of 24 research sites, established to acquire long-term data sets from Alaska to Puerto Rico to Antarctica. Such a geographical spread is necessary to collect information on a variety of ecosystem types, such as grassland, desert, forest, tundra, lake, stream, river, and agricultural and coastal systems.

To enhance understanding of ecological phenomena, the program focuses on the role of cyclical/episodic events (ranging from years to decades to centuries) in the structure and function of these distinctive ecosystems. The Antarctic Biology and Medicine Program supports two of these LTER project sites to facilitate research on unique aspects of antarctic ecology: one near Palmer Station in the Antarctic Peninsula and the other in the McMurdo Dry Valleys.

The Palmer Station/Antarctic Peninsula LTER program is ideally sited to probe a fundamental issue: As the pack ice varies (seasonally and year by year), what happens to the antarctic marine community? That is, how do ecological processes influence organisms at different trophic levels? The Palmer Station LTER program was initiated during the 1991-1992 season with the installation of an automatic meteorological station, annual research cruises in the austral summer, and a focused research program at the station facility. During the austral fall and spring seasons, process-study research cruises develop data that can be compared with data collected from other coastal systems in the Antarctic Peninsula.

Due to its unique site, the McMurdo Dry Valleys LTER project is more wide ranging and focuses on interdisciplinary study of aquatic and terrestrial ecosystems in a cold desert region of Antarctica. The area is one of the most fascinating and contrarian spots on Earth. In fact, it is almost unearthly. Scientists from the National Aeronautics and Space Administration who wondered what conditions might be like on Mars came here, an island of rock in a sea of ice, the largest ice-free area in Antarctica, where winds howl, where what little water there is dessicates or evaporates, and where the only creatures that can survive are microorganisms, mosses, lichens, and relatively few groups of invertebrates. Higher forms of life are virtually nonexistent.

Thus, LTER projects based here take advantage of perhaps the coldest and driest ecosystem on Earth, where life approaches its environmental limits; as such, this may be seen as an "end-member" in the spectrum of environments included in the LTER network. Why is it necessary to conduct long-term ecological research in such a place? All ecosystems depend on liquid water and are shaped to varying degrees by climate and material transport; but nowhere is this more apparent than in the McMurdo Dry Valleys. In very few of Earth's environments do minor changes in solar radiation and temperature so dramatically affect the capabilities of organisms to grow and reproduce as in the dry valleys. Therefore, this site may well be an important, natural, regional-scale laboratory for studying the biological effects of climate changes attributable to human activity. While the antarctic ice sheets respond to climate change on the order of thousands of years, the glaciers, streams, and ice-covered lakes in the McMurdo Dry Valleys often experience nearly immediate (and sometimes profound) change. As such, this area would be one of the first where the effects of climate change in Antarctica should be observed.

The overall objectives of the McMurdo Dry Valleys LTER are to understand the influence of physical and biological constraints on the structure and function of dry valley ecosystems and to understand the modifying effects of material transport on these ecosystems. Though driven by the same basic processes found in all ecosystems (microbial use and remineralization of nutrients, for example), these dry valley ecosystems lack many of the confounding variables, such as diverse and fecund biota and many levels of plants and higher animals, inherent in other ecosystem research.

The role of natural legacy on ecosystem structure and function in a polar desert: The McMurdo Dry Valley LTER program.
W. Berry Lyons, Ohio State University.

The largest ice-free area in Antarctica can be found in the McMurdo Dry Valleys, located on the western shore of McMurdo Sound. Among the most extreme deserts in the world, the dry valleys are the coldest and driest of all the LTER sites. Consequently, biological systems are limited to microbial populations, microinvertebrates, mosses, and lichens. Yet complex trophic interactions and biogeochemical nutrient cycles develop in the lakes, streams, and soils of the dry valleys. In the austral summer, solar energy produces glacial meltwater, providing vital water and nutrients that have a primary influence on the ecosystems. Such material transport and climatic influences shape all ecosystems, but nowhere is this more apparent than in the McMurdo Dry Valleys.

The McMurdo LTER project focuses on the aquatic and terrestrial ecosystems in the dry valley landscape as a context to study biological processes and to explore material transport and migration. During the second phase of this LTER project, we are extending our research by continuing to investigate the McMurdo Dry Valleys as an "end-member" system, hoping to better ascertain the role of past climatic legacies on ecosystem structure and function. We will test a series of eight hypotheses in three major focus areas-hydrology, biological activity/diversity, and biogeochemical processes-by continuing monitoring projects and long-term experiments.

Understanding the structure and function of the McMurdo Dry Valleys ecosystem requires deciphering the hydrological response to climate, both now and in the past. Current patterns of biological activity and diversity reflect past and present distributions of water, nutrients, organic carbon, and biota. Biogeochemical processes responsible for the transport, immobilization, and mineralization of nutrients and other chemicals provide the linkages between the region's biota and the physical environment. The timing, duration, and location of biogeochemical processes in the past and present are controlled by the availability of water. We continue to focus on the integration of the biological processes within and among the lakes, streams, and terrestrial ecosystems that comprise the McMurdo Dry Valley landscape. Our interdisciplinary research team will continue to use modeling and other integrative studies to synthesize data and to examine the McMurdo Dry Valleys ecosystem.

During the 2002-2003 field season, the following studies will be conducted in the McMurdo Dry Valleys as part of the LTER project:

- Paleoclimatology, paleoecology, and meteorological data collection. (BM-042-D; NSF/OPP 98-10219)
  Peter T. Doran, University of Illinois-Chicago.
- Glacier mass balance, melt, and energy balance: Climate monitoring in Taylor, Wright, Victoria, and Beacon valleys. (BM-042-F; NSF/OPP 98-10219)
  Andrew Fountain, Portland State University.
- Chemistry of streams, lakes, and glaciers. (BM-042-L; NSF/OPP 98-10219)
  W. Berry Lyons, Ohio State University.
- Flow, sediment transport, and productivity of streams; water quality of Lake Fryxell; water loss from the streams to the atmosphere by sampling water-content changes. (BM-042-M; NSF/OPP 98-10219)
  Diane McKnight, University of Colorado.
- Lake pelagic and benthic productivity: Microbial food webs. (BM-042-P; NSF/OPP 98-10219)
  John Priscu, Montana State University-Bozeman.
- The influence of environmental conditions on carbon and nitrogen cycling and on soil biota, the effects of environmental change and food supply availability on soil biota, and the effects of climate change on biota. (BM-042-V; NSF/OPP 98-10219)
  Ross A. Virginia, Dartmouth College.
- The influence of environmental conditions on carbon and nitrogen cycling and on soil biota, the effects of environmental change and food supply availability on soil biota, and the effects of climate change on biota. (BM-042-W; NSF/OPP 98-10219)
  Diana Wall, Colorado State University.

Long-term ecological research on the antarctic marine ecosystem: Climate change, ecosystem migration, and teleconnections in an ice-dominated environment.
Hugh W. Ducklow, College of William and Mary.

The Palmer Long-Term Ecological Research Project (PAL LTER) seeks to understand the structure and function of the antarctic marine and terrestrial ecosystem in the context of physical forcing by seasonal to interannual variability in atmospheric and sea-ice dynamics, as well as long-term climate change. The PAL LTER grid is designed to study marine and terrestrial food webs consisting principally of diatom primary producers, the dominant herbivore antarctic krill, *Euphausia superba*, and the apex predator Adélie penguin, *Pygoscelis adeliae*. An attenuated microbial food web, consisting of planktonic Archaea and bacterivorous protozoa, is also a focus of study.

This project monitors western Antarctic Peninsula ecosystems annually over a grid of oceanographic stations and seasonally at Palmer Station. Sea-ice extent and variability affect changes at all trophic levels. In recent years, sea ice has diminished in response to a general warming in the region. Long-term population trends of ice-dependent Adélie penguins provide a clear example of the impact of this trend in the Palmer study region. Adélie populations at the five major rookeries located near Palmer Station and studied for the past 30 years have all shown a gradual decrease in numbers. The western Antarctic Peninsula, the site of PAL-LTER research, runs perpendicular to a strong climatic gradient between the cold, dry continental regime to the south, characteristic of the interior, and the warm, moist maritime regime to the north. More maritime conditions appear to be replacing the original polar ecosystem in the northern part of the peninsula as the climatic gradient shifts southward. To date, this shift appears to be matched by an ecosystem shift along the peninsula, as evidenced by declines in Adélie penguins, which require longer snow-cover seasons.

We hypothesize that ecosystem migration is most clearly manifest by changes in upper-level predators (penguins) and certain polar fishes in predator foraging environments because these longer-lived species integrate recent climate trends (and because species are more sensitive indicators than aggregated functional groups). We hypothesize that in the years ahead, analogous modifications will be manifest at lower trophic levels in the marine parts of the system, although these changes are likely to be seen only through long-term studies of ecosystem boundaries along the peninsula.

By studying extant food webs in both the marine and terrestrial environments, we will continue to investigate ecosystem changes at lower trophic levels, in response to the continued, dramatic climate warming and shifts in the poleward climatic gradient along the Western Antarctic Peninsula.

During the 2002-2003 field season, the following studies will be conducted as part of the LTER project:

Long-term ecological research on the antarctic marine ecosystem: Climate change, ecosystem migration, and teleconnections in an ice-dominated environment.
William R. Fraser, Polar Oceans Research Group. (BP-013-P/L; NSF/OPP 02-17282)

Long-term ecological research on the antarctic marine ecosystem: Climate change, ecosystem migration, and teleconnections in an ice-dominated environment.
Maria Vernet, Scripps Institution of Oceanography. (BP-016-P/L; NSF/OPP 02-17282)

Long-term ecological research on the antarctic marine ecosystem: Climate change, ecosystem migration, and teleconnections in an ice-dominated environment.
Douglas G. Martinson, Columbia University. (BP-021-L; NSF/OPP 02-17282)

Long-term ecological research on the antarctic marine ecosystem: Climate change, ecosystem migration, and teleconnections in an ice-dominated environment.
Langdon B. Quetin, University of California-Santa Barbara. (BP-028-P/L; NSF/OPP 02-17282)

Long-term ecological research on the antarctic marine ecosystem: Climate change, ecosystem migration, and teleconnections in an ice-dominated environment.
Robin M. Ross, University of California-Santa Barbara. (BP-028-P/L; NSF/OPP 02-17282)

Long-term ecological research on the antarctic marine ecosystem: Climate change, ecosystem migration, and teleconnections in an ice-dominated environment.
Raymond C. Smith, College of William and Mary. (BP-032-P/L; NSF/OPP 02-17282)

Long-term ecological research on the antarctic marine ecosystem: Climate change, ecosystem migration, and teleconnections in an ice-dominated environment. (microbial and carbon flux).
Hugh Ducklow, College of William and Mary. (BP-045-P; 0087872)

Transport and fate of persistent organic pollutants in antarctic coastal seas.
Hugh Ducklow, College of William and Mary.

Being distant and largely isolated from the industrialized world, the antarctic region is typically considered pristine. In the past two decades, however, concern about long-range atmospheric transport of persistent organic pollutants (POPs) has escalated across the globe. POPs are highly stable organic compounds that persist in the environment, accumulate in the fatty tissues of most living organisms, and are generally toxic to humans and wildlife. They come from pesticides and industrial and combustion processes.

But Antarctica is not just another place that could suffer the random, transboundary drifting of these noxious substances. Its polar location and unparalleled climatic characteristics raise unique issues of atmospheric transport, cold condensation, and deposition on sea ice. Because the climate changes so dramatically, sea ice comes and goes, covering as little as 4 million square kilometers (sq km) in February to as much as 20 million sq km in September. Vast webs of microbial life undergo seasonal production and decomposition. Antarctic food webs are thus vulnerable to those POPs that do migrate that far.

Cooperating with the Palmer Long-Term Ecological Research program (LTER) and sailing on its winter cruise on the R/V *Nathaniel B. Palmer*, we hope to document the accumulation of selected model POPs in sea ice and the water column along the west Antarctic Peninsula. We also hope to add to the burgeoning global data set on the biological/chemical processes that influence the rate of POP decline, turnover, and residence time. (BP-045-P; NSF/OPP 00-87872)